METHOD FOR FORMING ULTRA HARD SINTERED COMPACTS USING METALLIC PERIPHERAL STRUCTURES IN THE SINTERING CELL

BACKGROUND OF THE INVENTION

Sintered ultra hard material cutting elements such as tips for metal machining inserts, for example, typically include an ultra hard cutting layer bonded to a substrate, forming what is often referred to as a compact. The ultra hard cutting layer is generally formed by a high pressure, high temperature (HPHT) sintering process and the cutting layer is typically bonded to the substrate during the sintering process.

The ultra hard sintered compact is generally formed from particles of ultra hard material that are compacted and solidified during the sintering process. The ultra hard particles may be in powder form prior to sintering. Ultra hard particles used to form sintered compacts include diamond and cubic boron nitride, which form polycrystalline diamond (PCD) and polycrystalline cubic boron nitride (PCBN), respectively.

Sintered compacts are conventionally formed by placing ultra hard material particles within a refractory metal enclosure and sintering the enclosure and contents under HPHT conditions. A shortcoming associated with this conventional formation process is that the high-pressure, high temperature heating process and subsequent cooling process, produce an ultra hard material layer having a periphery that includes edge cracks, chips and fractures. These edge cracks, chips and fractures typically initiate at the enclosure and continue growing into to the compact ultra hard material layer. This cracking, chipping, fracturing, etc. renders the outer portion of the ultra hard material layer unusable. Fracturing, cracking, and chipping is especially prevalent when forming relatively large (more than 50 mm diameter) ultra hard material layers. To avoid sintered compacts being delivered to customers having peripheries that include the above-mentioned defects, a significant amount of the outer portions of the PCD or PCBN sintered compacts must be removed, therefore reducing the useable diameter of the sintered compacts. This results in higher raw material waste and costs, higher processing costs, and lower HPHT press capacity efficiency and utilization. For example, using conventional methods,

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a disk-shaped sintered compact formed to a diameter of 58 mm, may include edge fracturing and cracking that requires the formed sintered compact to have parts of the peripheral portion removed resulting in a useable diameter of only 50-52 mm or less. In particular, according to the prior art, most sintered compacts formed to a diameter of 58 millimeters, for example, are finished to a diameter less than 55 mm.

Accordingly, it would therefore be desirable to produce an ultra hard cutting layer in which the high quality, useable cutting area is maximized.

SUMMARY OF THE INVENTION

To address the aforementioned concerns and in view of its purposes, the present invention provides an exemplary method for forming an ultra hard layer or a compact. The method includes providing a refractory metal enclosure having an inner wall, disposing a metallic liner within the enclosure, disposing ultra hard material particles within the enclosure, and sintering to convert the ultra hard material particles to a solid ultra hard layer that may be used as a cutting layer.

In another exemplary embodiment, a method is provided for forming an ultra hard layer or a compact, including providing a refractory metal enclosure having an inner wall and disposing a liner within said enclosure. The method further requires placing ultra hard material feed stock within the enclosure, placing a substrate material within the enclosure over the feed stock layer, and sintering to convert the ultra hard material feed stock to a solid ultra hard layer, where a melting temperature of a eutectic formed during sintering between the liner, a compound of the ultra hard material and the enclosure is in the range of about 1100° to 1410°C.

In a further exemplary embodiment, a method is provided for forming an ultra hard layer, including providing a refractory metal enclosure having an inner wall, and disposing a liner within said enclosure, the liner having a melting temperature lower than the enclosure. The method also requires placing ultra hard material feed stock within said enclosure, and sintering to convert said ultra hard material feed stock to a solid ultra hard layer.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is best understood from the following detailed description when read in conjunction with the accompanying drawings. It is emphasized that, according to common practice, the various features of the drawings are not to-scale. On the contrary, the dimensions of the various features are arbitrarily expanded or reduced for clarity. Like numerals denote like features throughout the specification and drawings. Included are the following figures:

Figure 1 is a cross-sectional view showing an exemplary refractory metal enclosure including a peripheral metallic liner therein;

Figure 2 is a perspective view showing a liner ring and a refractory metal disc prior to being shaped into an enclosure;

Figure 3 is a cross-sectional view showing a punch and die used to punch the components shown in Figure 2, into a refractory metal enclosure with the metallic liner therein;

Figure 4 is a perspective view showing another exemplary arrangement for positioning a metallic liner ring within an enclosure;

Figure 5 is a cross sectional view showing a substrate and ultra hard particles within an enclosure; and

Figure 6 is a cross-sectional view showing an ultra hard layer bonded to a substrate.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides in an exemplary embodiment, a method for producing an ultra hard material sintered layer or compact with a peripheral edge substantially free of fracturing, cracking and chipping. The exemplary method includes providing a refractory metal enclosure and providing a metallic liner, coating or layer (collectively or individually referred to as metallic liner hereinafter) within the enclosure. Particles of ultra hard material such as an ultra hard material feed stock are introduced into the enclosure and the material is then sintered using HPHT processing.

Figure 1 is a cross-sectional view showing enclosure 1 formed of refractory metal material 3. Enclosure 1 may be alternatively referred to as a can or a cell. Enclosure 1 includes inner wall 11 and, in an exemplary embodiment may be cylindrical. In such an embodiment, the inner wall 11 may be a single continuous inner peripheral wall that is cylindrical in shape. For illustrative purposes, enclosure 1 will be discussed in terms of being generally cylindrical and having an inner peripheral wall 11, but it should be understood that such is exemplary only and in other exemplary embodiments, enclosure 1 may take on various different shapes and may include a plurality of inner walls which may take on various configurations. For example, enclosure 1 may take on other shapes such as elliptical or oblong shapes, or other parabolic or rectilinear shapes. Refractory metal material 3 forming enclosure may be niobium, Nb, tantalum, Ta, molybdenum, Mo, or another suitable refractory metal material as for example a member of the IVB, VB, and VIB families of the periodic table. Within enclosure 1 and adjacent inner peripheral wall 11 in the illustrated exemplary embodiment is placed metallic liner 5. In an exemplary embodiment, the metallic liner 5 has a melting temperature lower than the melting temperature of enclosure 1. Metallic liner 5 may be formed of cobalt, Co, nickel, Ni, iron, Fe, steel, or alloys of the aforementioned materials. In one exemplary embodiment, an 95:5 cobalt-iron metallic liner 5 may be used. Such materials are intended to be exemplary only and in other exemplary embodiments, other suitable metallic materials may be used to form metallic liner 5. Metallic liner 5 includes thickness 7 which may be within the range of 0.005mm to 3mm in an exemplary embodiment, but other suitable thicknesses may be used in other exemplary embodiments. Although metallic liner 5 is shown adjacent inner peripheral wall 11 it should be understood that metallic liner 5 may be spaced from inner peripheral wall 11 prior to the introduction of the particles of ultra hard material (as will be shown later). Enclosure 1 has an inner diameter 9 defined by inner peripheral wall 11 and in an exemplary embodiment, inner diameter 9 may range from 40-80 mm. In one particular exemplary embodiment, inner diameter 9 may lie within the range of 55-60 mm.

Metallic liner 5 may be positioned within enclosure 1 using various mechanical techniques. In one exemplary embodiment, metallic liner 5 may simply be placed

within enclosure 1 by hand or using other manual techniques. For example, the metallic liner may be a layer of metallic material applied using various well known methods, such as spraying or brushing. In another exemplary embodiment, the metallic liner and enclosure may be shaped and arranged simultaneously using metal drawing techniques. For example, as shown in Figure 2, a metallic liner 5' having a generally annular shape, is placed over a substantially flat disk of refractory metal material 3, and then mechanically shaped to form the enclosure 1/metallic liner 5 arrangement shown in Figure 1 by being positioned in the punch/die arrangement shown in Figure 3, then punched. According to the cross-sectional schematic shown in Figure 3, punch 15 moves in direction 19 to force the disk of refractory metal material 3 and metallic liner 5' into die 17 thereby shaping the refractory metal material 3 and the annular shaped metallic liner 5' generally into the configuration shown in Figure 1 where enclosure 1 is lined with metallic liner 5.

Figure 4 is a perspective view showing another exemplary embodiment for forming enclosure 1 of refractory metal material 3 and including metallic liner 5 therein, as shown in Figure 1. According to the embodiment shown in Figure 4, enclosure 1, formed of refractory metal material 3, is pre-formed and a strip of liner 5" is formed in a cylindrical shape and inserted within pre-formed enclosure 1. In one exemplary embodiment, after the strip of metallic liner 5" is arranged in a cylindrical shape, it is then spot welded such as at spot weld points 23, to connect its respective opposed ends. Other techniques for forming a generally cylindrical metallic liner 5" and for positioning the same within enclosure 1, may be used in other exemplary embodiments.

Figure 5 shows exemplary enclosure 1, previously shown in Figure 1, after particles of ultra hard material and a substrate 29 have been introduced into enclosure 1. Particles of ultra hard material 27 are added to enclosure 1 and may be in powder form. Particles of ultra hard material 27 may be cubic boron nitride or diamond feed stocks for forming sintered PCD or PCBN of various compositions. In the exemplary embodiment illustrated in Figure 5, substrate 29 is also disposed within enclosure 1. Substrate 29 may be formed of WC-Co or WC-Ni or other suitable materials. In other exemplary embodiments, substrate 29 is not added within enclosure 1, thus, a mono-block product, such as an ultra hard layer is

formed. According to such exemplary embodiment, after the particles of ultra hard material 27 are sintered using an HPHT process to form an ultra hard layer, the ultra hard layer may be used as a cutting layer or joined to a separately formed substrate to form a cutting element.

It can be seen in the illustrated exemplary embodiment that metallic liner 5 is adjacent inner peripheral wall 11 of enclosure 1, and interposed between inner peripheral wall 11 and particles of ultra hard material 27. In this manner, peripheral portions of the layer of particles of ultra hard material 27, as well as substrate 29, contact metallic liner 5 and do not contact inner peripheral walls 11 of the enclosure directly. In an exemplary embodiment, after the materials are introduced into enclosure 1, the enclosure is covered by a refractory metal cover 31 as shown in Figure 5, and enclosure 1 and its contents are sintered using HPHT processing. In the illustrated exemplary embodiment, refractory metal cover 31 is formed from the same material as enclosure 1. Conventional HPHT pressing techniques may be used. In one exemplary embodiment, the sintering process may utilize heating to a temperature within the range of 1200-1600°C and using a pressure of up to 40-65 kilobars. After the sintering process, the enclosure and its contents are cooled and the pressure is reduced to ambient conditions.

During the sintering and cooling processes, the layer of particles of ultra hard material 27 is sintered and thereby converted to a polycrystalline ultra hard material layer. According to the embodiments in which substrate 29 is present in the enclosure, the sintering process bonds the formed ultra hard layer to substrate 29. During the sintering process, the metallic material that forms metallic liner 5, and which contacts particles of ultra hard material 27, in particular around the periphery, forms a molten alloy region which becomes a plastically deformable region during the cooling stage following HPHT sintering.

During the HPHT sintering, materials from metallic liner 5 may infiltrate peripheral portions of the layer of particles of ultra hard material 27. The metallic liner is in the exemplary embodiment chosen to posses similar melting/solidifying temperatures as the substrate materials, therefore alleviating the stresses on the periphery. The ferrous family of metals forming the liner are chosen to form liquid eutectics which solidify at temperatures very similar to the liquid eutectic

temperatures found in the substrate material. In an exemplary embodiment, no more than about the outer 500 micron peripheral portion of the ultra hard material may be so infiltrated. Applicants have discovered that the HPHT sintering and cooling processes convert the layer of particles of ultra hard material 27 to a solid polycrystalline ultra hard layer that is substantially or completely free of cracks, chips, fractures and other defects substantially throughout the formed sintered compact.

In conventional HPHT sintering of PCD and PCBN in refractory metal enclosures made of Nb or Ta, the melting temperatures of the binary compounds formed are typically greater than 1770°C. For example when sintering cubic boron nitride in a Nb enclosure an Nb-B and/or Nb-N binary system is formed with no eutectic. When sintering diamond in a Nb enclosure an Nb-C binary is formed with no eutectic. When sintering cubic boron nitride in a Ta enclosure, a binary system Ta-B may be formed having a eutectic having a melting temperature of about 1770°C or a Ta-N binary system is formed having no eutectic. If diamond is sintered in a Ta enclosure a Ta-C binary system may be formed having a eutectic having a melting temperature of about 2800 °C.

When using a Co, Ni, or Fe liner in a Nb or Ta enclosure during sintering, binary systems are formed having eutectics having melting eutectic temperatures as shown in Tables 1 and 2, respectively, below.

Binary System	Eutectic Melting Temperature, °C
Nb-Co	1235
Nb-Ni	1270
Nb-Fe	1360

Table 1. Eutectic Melting Temperatures in an Nb enclosure.

Binary System	Eutectic Melting Temperature, °C
Ta-Co	1276
Ta-Ni	1360
Ta-Fe	1410

Table 2. Eutectic Melting Temperatures in a Ta enclosure.

When sintering cubic boron nitride or diamond in an enclosure lined with a Co, Ni, or Fe liner, binary systems are formed having eutectics having the melting temperatures as shown in Tables, 3 and 4, respectively.

Binary System	Eutectic Melting Temperature, °C
B-Co	1102
B-Ni	1140
B-Fe	1149
N-Co	N almost non soluble in Co
N-Ni	N almost non soluble in Ni
N-Fe	2.8wt% N soluble in Fe at 650C

Table 3. Eutectic Melting Temperatures of Binary Systems formed during Sintering of CBN in Metallic Liners

Binary System	Eutectic Melting Temperature, °C
C-Co	1309
C-Ni	1318
C-Fe	1153

Table 4. Eutectic Melting Temperatures of Binary Systems formed during Sintering of diamond in Metallic Liners

As can be seen the eutectics formed between the liner and the enclosure and between the enclosure and the diamond of cubic boron nitride have a melting temperature from around 1102°C to 1410°C and as such are much closer to the substrate (WC-Co) eutectic melting temperature of about 1320°C then are the melting temperatures of the eutectics formed when no metallic liners are used. Consequently, these eutectics and the substrate solidify at temperatures during the cooling stage of the HPHT sintering process that are closer together than when not using the exemplary metallic liners thus reducing the stresses and consequential cracking, pitting and fracturing that is evident when sintering without the liners.

In an exemplary embodiment, the liners are chosen to form eutectics having a melting temperature within 310°C of the eutectic melting temperature of the substrate. Moreover, the lower melting point eutectic formed via the metallic liner between the refractory metal enclosure and the cubic boron nitride or diamond, as compared with the higher melting temperature eutectics formed when no liner is used, acts as a "liquid shell" which solidifies at a similar temperature range with the substrate during the cooling stage of the HPHT sintering process, retarding and/or arresting the growth of cracks, and fractures and thus, chips, that typically initiate at the enclosure from progressing into the compact or ultra hard material. Consequently the compacts or ultra hard material layers formed using the exemplary embodiment method are substantially or completely free of cracks, fractures and chips at their ultra hard material peripheries.

In the embodiment where the ultra hard material layer is sintered without a substrate, the liner is chosen to form a eutectic with the enclosure and/or a compound of the ultra hard material having a melting temperature in the range of about 1100°C to about 1410°C.

Figure 6 shows an exemplary embodiment of an ultra hard layer 31 bonded to substrate 29 and formed using enclosure 1 and the layer of particles of ultra hard materials 27. Ultra hard layer 31 may be formed of polycrystalline cubic boron nitride (PCBN), polycrystalline diamond (PCD) or other suitable ultra hard materials. Ultra hard layer 31 includes surface 39 and diameter 35. In an exemplary embodiment, diameter 35 may range from 40 - 100 mm. In one particular exemplary embodiment,

ultra hard layer 31 may be disk shaped and diameter 35 may be at least 55mm, for example, it may be 58mm.

Ultra hard layer 31 also includes thickness 41, which may be about "0.5mm to 5mm" in an exemplary embodiment, but various other thicknesses may be used in other exemplary embodiments. Diameter 35 of ultra hard layer 31 is substantially equal to inner diameter 9 of enclosure 1. Substantially all of the ultra hard layer 31 formed according to the present invention is free of cracks, chips, voids and fractures. Consequently, substantially the entire ultra hard layer formed using enclosure 1, is usable as an ultra hard surface such as an ultra hard cutting surface. In an exemplary embodiment the peripheral portion of ultra hard layer 31 that was infiltrated with metal materials from metallic liner 5, may be removed using well known methods. In one exemplary embodiment, less than 500 microns of the peripheral edge may be so infiltrated and removed.

In an exemplary embodiment, the invention may be used from cutting elements such as shear cutters which are mounted on a bit body.

The preceding merely illustrates the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements which, although not explicitly described or shown herein, embody the principles of the invention and are included within its scope and spirit. For example, the ultra hard cutting layer may be formed to different shapes and different sizes. The HPHT sintering conditions and cooling conditions, as well as the thickness and placement of the metallic liner, may be varied and still lie within the scope of the invention.

Furthermore, all examples and conditional language recited herein are principally intended expressly to be only for pedagogical purposes and to aid in understanding the principles of the invention and the concepts contributed by the inventors to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass both structural and the functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents and equivalents developed in the future, i.e., any elements developed that perform the same function, regardless of structure. The

scope of the present invention, therefore, is not intended to be limited to the exemplary embodiments shown and described herein. Rather, the scope and spirit of the present invention is embodied by the appended claims.